CLAIMS

1. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness consisting of:

C : 0.03 to 0.07 mass%
Si : not more than 0.6 mass%
Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
S : not more than 0.003 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
Ti : 0.005 to 0.030 mass%
Al : not more than 0.10 mass%

and, one or more of:

Ni : 0.1 to 1.5 mass%
B : less than 3 ppm
V : not more than 0.10 mass%
Cu : not more than 1.0 mass%
Cr : not more than 1.0 mass%
Ca : not more than 0.01 mass%
REM : not more than 0.02 mass%
Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0, in which;

the ratio $(Hv\text{-}ave_p)/(Hv\text{-}M)$ between the average Vickers hardness $Hv\text{-}ave_p$ in the direction of thickness and the martensitic hardness Hv-M determined by carbon content is between 0.8 and 0.9, and the transverse tensile strength $TS\text{-}T_p$ is between 880 MPa and 1080 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + Mo - 1$$

$$Hv\text{-}M = 270 + 1300C$$

wherein the symbols of elements designate the mass% of the individual elements.

2. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness consisting of:

C : 0.03 to 0.07 mass%

Si : not more than 0.6 mass%
Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
S : not more than 0.003 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
Ti : 0.005 to 0.030 mass%
Al : not more than 0.10 mass%
B : 3 ppm to 0.0025 mass%
and, one or more of:
Ni : 0.1 to 1.5 mass%
N : 0.001 to 0.006 mass%
V : not more than 0.10 mass%
Cu : not more than 1.0 mass%
Cr : not more than 1.0 mass%
Ca : not more than 0.01 mass%
REM : not more than 0.02 mass%
Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0, in which;
the ratio $(Hv\text{-}ave_p)/(Hv\text{-}M)$ between the average Vickers hardness $Hv\text{-}ave_p$ in the direction of thickness and the martensitic hardness Hv-M determined by carbon content is between 0.8 and 0.9, and the transverse tensile strength $TS\text{-}T_p$ is between 880 MPa and 1080 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + 2Mo$$

$$Hv\text{-}M = 270 + 1300C$$

wherein the symbols of elements designate the mass% of the individual elements.

3. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in claim 1 or 2, containing:

N : 0.001 to 0.006 mass%.

4. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in

claim 3, in which the relationship Ti - 3.4 N > 0 is satisfied (wherein the symbols of elements designate the mass% of the individual elements).

5. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 1 to 4, in which the V-notch Charpy value at -20 °C is not lower than 200J.

6. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 1 to 5, in which the longitudinal tensile strength TS-L_p is not greater than 0.95 times the transverse tensile strength TS-T_p.

7. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 1 to 6, in which the yield ratio in the direction of rolling (YS - L_p)/(TS - L_p), which is the ratio of the 0.2% offset yield strength YS - L_p in the direction of rolling to the tensile strength TS - L_p in the direction of rolling is not greater than 0.8.

8. Ultra-high-strength linepipe having excellent low-temperature toughness prepared by seam-welding steel plate consisting of:

C : 0.03 to 0.07 mass%
Si : not more than 0.6 mass%
Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
S : not more than 0.003 mass%
Ni : 0.1 to 1.5 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
Ti : 0.005 to 0.030 mass%
Al : not more than 0.06 mass%

and, one or more of:

B : not more than 0.0025 mass%
N : 0.001 to 0.006 mass%
V : not more than 0.10 mass%
Cu : not more than 1.0 mass%

Cr : not more than 1.0 mass%
Ca : not more than 0.01 mass%
REM : not more than 0.02 mass%
Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0, in which;

the ratio (Hv-ave)/(Hv-M) between the average Vickers hardness Hv-ave in the direction of thickness of the base metal and the martensitic hardness Hv-M determined by carbon content is between 0.8 and 0.9 and the circumferential tensile strength TS-C is between 900 MPa and 1100 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + (1 + \beta)Mo - 1+\beta$$

where $\beta = 1$ when $B \geq 3$ ppm and $\beta = 0$ when $B < 3$ ppm

$$Hv\text{-}M = 270 + 1300C$$

wherein the symbols of elements designate the mass% of the individual elements.

9. Ultra-high-strength linepipe having excellent low-temperature toughness prepared by seam-welding steel plate consisting of:

C : 0.03 to 0.07 mass%
Si : not more than 0.6 mass%
Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
S : not more than 0.003 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
Ti : 0.005 to 0.030 mass%
Al : not more than 0.10 mass%

and, one or more of:

Ni : 0.1 to 1.5 mass%
B : less than 3 ppm
V : not more than 0.10 mass%
Cu : not more than 1.0 mass%
Cr : not more than 1.0 mass%

Ca : not more than 0.01 mass%
REM : not more than 0.02 mass%
Mg : not more than 0.006 mass%
and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0, in which;
the ratio (Hv-ave)/(Hv-M*) between the average Vickers hardness Hv-ave in the direction of thickness of the base metal and the martensitic hardness Hv-M* determined by carbon content is between 0.75 and 0.9 and the circumferential tensile strength TS-C is between 900 MPa and 1100 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + Mo - 1$$

$$Hv\text{-}M^* = 290 + 1300C$$

wherein the symbols of elements designate the mass% of the individual elements.

10. Ultra-high-strength linepipe having excellent low-temperature toughness prepared by seam-welding steel plate consisting of:
C : 0.03 to 0.07 mass%
Si : not more than 0.6 mass%
Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
S : not more than 0.003 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
Ti : 0.005 to 0.030 mass%
Al : not more than 0.10 mass%
B : 3 ppm to 0.0025 mass%
and, one or more of:
Ni : 0.1 to 1.5 mass%
N : 0.001 to 0.006 mass%
V : not more than 0.10 mass%
Cu : not more than 1.0 mass%
Cr : not more than 1.0 mass%
Ca : not more than 0.01 mass%

REM : not more than 0.02 mass%

Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0, in which;

the ratio (Hv-ave)/(Hv-M*) between the average Vickers hardness Hv-ave in the direction of thickness of the base metal and the martensitic hardness Hv-M* determined by carbon content is between 0.75 and 0.9 and the circumferential tensile strength TS-C is between 900 MPa and 1100 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + 2Mo$$

$$Hv\text{-}M^* = 290 + 1300C$$

wherein the symbols of elements designate the mass% of the individual elements.

11. Ultra-high-strength linepipe having excellent low-temperature toughness described in claim 9 or 10 containing:

N : 0.001 to 0.006 mass%.

12. Ultra-high-strength linepipe having excellent low-temperature toughness described in claim 11, in which the relationship $Ti - 3.4\ N > 0$ is satisfied (wherein the symbols of elements designate the mass% of the individual elements).

13. Ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 8 to 12, in which the V-notch Charpy value at -20 °C is not lower than 200J.

14. Ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 8 to 13, in which the tensile strength in the longitudinal direction of linepipe is not greater than 0.95 times the tensile strength in the circumferential direction thereof.

15. A method for manufacturing steel plate for ultra-high-strength linepipe having excellent low-

temperature toughness comprising the steps of:

heating slabs consisting of:

C : 0.03 to 0.07 mass%
Si : not more than 0.6 mass%
Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
S : not more than 0.003 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
Ti : 0.005 to 0.030 mass%
Al : not more than 0.10 mass%

and, one or more of:

Ni : 0.1 to 1.5 mass%
B : less than 3 ppm
V : not more than 0.10 mass%
Cu : not more than 1.0 mass%
Cr : not more than 1.0 mass%
Ca : not more than 0.01 mass%
REM : not more than 0.02 mass%
Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0 and between 1000 and 1250 °C,

rough rolling in a recrystallizing region,

rolling in an unrecrystallization austenitic region at 900 °C or below with a cumulative rolling reduction of not less than 75% and, then,

applying accelerated cooling from the austenitic region so that the center of plate thickness cools to 500 °C or below at a rate of 1 to 10 °C/sec.,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + Mo - 1$$

wherein the symbols of elements designate the mass% of the individual elements.

16. A method for manufacturing steel plate for ultra-high-strength linepipe having excellent low-

temperature toughness comprising the steps of:

heating slabs consisting of:

C : 0.03 to 0.07 mass%
Si : not more than 0.6 mass%
Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
S : not more than 0.003 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
Ti : 0.005 to 0.030 mass%
Al : not more than 0.10 mass%
B : 3 ppm to 0.0025 mass%

and, one or more of:

Ni : 0.1 to 1.5 mass%
N : 0.001 to 0.006 mass%
V : not more than 0.10 mass%
Cu : not more than 1.0 mass%
Cr : not more than 1.0 mass%
Ca : not more than 0.01 mass%
REM : not more than 0.02 mass%
Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0 and between 1000 and 1250 °C,

rough rolling in a recrystallized region,

rolling in an unrecrystallization austenitic region at 900 °C or below with a cumulative rolling reduction of not less than 75% and, then,

applying accelerated cooling from the austenitic region so that the center of plate thickness cools to 500 °C or below at a rate of 1 to 10 °C/sec.,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + 2Mo$$

wherein the symbols of elements designate the mass% of the individual elements.

17. A method for manufacturing steel plate for

ultra-high-strength linepipe having excellent low-temperature toughness described in claim 15 or 16, in which slabs also contain

N : 0.001 to 0.006 mass%.

18. A method for manufacturing steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in 17, in which the relationship Ti - 3.4 N > 0 is satisfied (wherein the symbols of elements designate the mass% of the individual elements).

19. A method for manufacturing ultra-high-strength linepipe having excellent low-temperature toughness comprising the steps of:

forming a steel plate manufactured by the methods for manufacturing ultra-high-strength steel plate having excellent low-temperature toughness described in any of claims 15 to 18 into a pipe form so that the rolling direction of the steel plate agrees with the longitudinal direction of a pipe to be manufactured, and

forming a pipe by seam-welding together the edges thereof.

20. A method for manufacturing ultra-high-strength linepipe having excellent low-temperature toughness comprising the steps of:

forming a steel plate manufactured by the methods for manufacturing ultra-high-strength steel plate having excellent low-temperature toughness described in any of claims 15 to 18 into a pipe form by the UO process so that the rolling direction of the steel plate agrees with the longitudinal direction of a pipe to be manufactured,

forming a pipe by joining together the edges thereof by applying submerged-arc welding from both inside and outside, and

expanding the welded pipe.

21. A method for manufacturing ultra-high-strength linepipe having excellent low-temperature toughness comprising the steps of:

heating slabs consisting of:

C	:	0.03 to 0.07 mass%
Si	:	not more than 0.6 mass%
Mn	:	1.5 to 2.5 mass%
P	:	not more than 0.015 mass%
S	:	not more than 0.003 mass%
Ni	:	0.1 to 1.5 mass%
Mo	:	0.15 to 0.60 mass%
Nb	:	0.01 to 0.10 mass%
Ti	:	0.005 to 0.030 mass%
Al	:	not more than 0.06 mass%

and, one or more of:

B	:	not more than 0.0025 mass%
N	:	0.001 to 0.006 mass%
V	:	not more than 0.10 mass%
Cu	:	not more than 1.0 mass%
Cr	:	not more than 1.0 mass%
Ca	:	not more than 0.01 mass%
REM	:	not more than 0.02 mass%
Mg	:	not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0 and between 1000 and 1250 °C,

rough rolling in a recrystallized region,

rolling in an unrecrystallization austenitic region at 900 °C or below with a cumulative rolling reduction of not less than 75%,

applying accelerated cooling from the austenitic region so that the center of plate thickness cools to 500 °C or below at a rate of 1 to 10 °C/sec.,

forming the steel plate thus manufactured into a pipe form so that the rolling direction of the steel plate agrees with the longitudinal direction of a pipe to be manufactured, and

forming a pipe by welding together the edges thereof.

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + (1 + \beta)Mo - 1+\beta$$

where $\beta = 1$ when $B \geq 3$ ppm and $\beta = 0$ when $B < 3$ ppm

wherein the symbols of elements designate the mass% of the individual elements.

22. A method for manufacturing ultra-high-strength linepipe having excellent low-temperature toughness described in claim 21, which furthermore comprising the steps of:

forming the steel plate subjected to accelerated cooling into a pipe form by the UO process so that the rolling direction of the steel plate agrees with the longitudinal direction of a pipe to be manufactured,

joining the edges thereof together by applying submerged-arc welding from both inside and outside, and

expanding the welded pipe.